Initial Economic and Operations Data Base for DSS 13 Automation Test

D. S. Remer
Communications Systems Research Section
and Harvey Mudd College

G. Lorden
California Institute of Technology

This article summarizes the data base collected for nine weeks of recent operation at DSS 11. Life cycle cost (LCC) parameters on efficiency and productivity ratios, costs, and telemetry were calculated from this data base. The data base and LCC parameters will be used as part of the economic and performance evaluation of the operations demonstration of running DSS 13 unattended and remotely controlled from JPL. The results will enable a comparison to be made between the remote operation of telemetry at DSS 13 with the cost and performance of a comparable manned operation at DSS 11.

I. Introduction

Over the last decade, there has been a gradual increase in automation of the DSN to reduce manpower and to improve network productivity. For example, the crew size at DSS 12 has been reduced by 80 percent since 1967. The next major step is to completely automate a station so that no operators are required. Such an experiment is now underway at DSS 13. This automated station is being run unattended and remotely controlled from JPL in Pasadena. This automation demonstration has three objectives:

(1) To see if an unattended operation can be accomplished.

(2) To collect operations data so an evaluation of unattended operation can be performed.

(3) To provide a single point, remote, unattended control of DSS 13 to accomplish Voyager spacecraft telemetry reception and transmission to the Network Operations Control Center (NOCC) via DSS 12 during DSS 12 downtime for S/X upgrade from a 26-meter to a 34-meter antenna.

A previous article (Ref. 1) was concerned with the second objective, namely, what data do we collect, how do we analyze the data, and what can and cannot be learned from this automation demonstration test? In that article, the goals of the test were outlined and LCC parameters were developed for comparing the unattended remote operation of telemetry at DSS 13 with the operation of a typical DSN manned station, namely DSS 11. It is hoped that this comparison will give valuable insight into the advantages and disadvantages of automated remote operation compared to our present method of manned operation throughout the network.

In this article we will present preliminary data collected at DSS 11 over a nine-week period. Also, we will describe the life cycle cost parameters computed from this data base.

II. DSS 11 Data Base

During the nine-week period of May 14, 1978, to July 9, 1978, a preliminary data base was collected on the operation of DSS 11. This data base serves two purposes. First, it allows us to check the data base requirements outlined in a previous paper (Ref. 1) and make necessary adjustments. Second, it serves as a bench mark to compare future data from both DSS 11 and DSS 13 during the actual automation demonstration. Data base requirements for this test period were scaled down because no additional station data could be collected at DSS 11 over and above what is normally collected at the station as a result of the contractor turnover and the resulting shortage of operations manpower.

A summary of the data collected is shown in Tables 1 through 3. The life cycle cost parameters calculated from this data base are summarized in Table 4. The definitions of these LCC parameters are also given in Table 4. For a more detailed development of these LCC factors, see Ref. 1.

III. Discussion of Results

A. Efficiency and Productivity Ratios

The first two LCC parameters are efficiency and productivity ratios. These ratios are concerned with comparing end user hours to station operating hours and M&O manhours as shown below:

$$\text{Efficiency ratio} = \frac{\text{EUH/unit time}}{\text{SOH/unit time}}$$

where

SOH = station operating hours: those hours when a station is required to be available to conduct DSN activities. (SOH are usually 40, 80, 120, 160, or 168 hours per week).

EUH = end user hours: those station operating hours where data, test, or training information is obtained for the end user.

$$\text{Productivity ratio} = \frac{\text{EUH/unit time}}{\text{M\&O MH/unit time}}$$

where

M&O MH = the manhours spent on operations, corrective and preventive maintenance, and training.

Most of the data were collected in weekly increments so the "unit time" is a week for this data base.

The station operating hours (SOH) were usually 160 hours per week, while the end user hours (EUH) varied from a low of 96.7 to a high of 109.4 hours per week. The allocation of EUH and SOH for the entire period is summarized in Tables 2 and 3. Note that personnel training accounted for 8 percent of SOH. This will probably be greatly reduced with automation. The total M&O manhours varied a lot more from week to week than the SOH and EUH. For example, the EUH and weekly manhours for operations, training, corrective maintenance, and preventive maintenance are shown below.

	Mean	Standard deviation	Coefficient of variation
End user hours	102.8	4.6	4.5%
Operation manhours	326.8	36.9	11.3%
Training manhours	130.7	52.1	39.9%
Corrective maintenance manhours	153.5	65.6	42.7%
Preventive maintenance manhours	56.4	35.1	62.2%

From the above table, we see that the coefficient of variation, which is the standard deviation as a percent of the mean, increases from 4.5 percent for end user hours to 62.2 percent for preventive maintenance. Also note that preventive maintenance is a lot more variable than corrective maintenance manhours, and maintenance manhours are a lot more variable than operations. A summary of the productivity and efficiency ratios is shown in Table 4.

Another interesting observation is that there are about twice as many manhours for operations (including training) as for maintenance. Though automation has a dramatic effect on reducing operations manhours, its effect upon maintenance manhours is not clear. There is the potential for designing automated systems to improve isolation and diagnosis of failures. On the other hand, there is the need to maintain the additional equipment required for automation. We hope to gain some insight into maintenance requirements of automation equipment from the DSS-13 demonstration.

B. Cost Parameters

Now that we have looked at manhours, let's consider costs. We will examine two costs: end user hourly M&O cost and station hourly M&O cost. In our calculations, we used current hourly labor costs that include contractor and JPL burden.

The following LCC parameters were calculated in order to compare the maintenance and operations costs at a station per end user hour. There is a separate parameter for operations and another for maintenance, because we expect that unattended operation will reduce operating manpower costs but may increase maintenance costs as a result of the additional equipment required. We also divided maintenance costs into preventive and corrective. The following definition was used to calculate end user hourly M&O cost.

$$\text{End user hourly M\&O cost} = \frac{\text{M\&O cost \$/unit time}}{\text{EUH/unit time}}$$

The M&O cost is made up of four components:

(1) Corrective maintenance

(2) Preventive maintenance

(3) Operations

(4) Training

For each of these components an hourly cost was calculated by using the following four equations. Only manpower costs are included in this M&O analysis.

$$\text{End user hourly corrective maintenance cost} = \frac{\text{Corrective maintenance cost \$/unit time}}{\text{EUH/unit time}}$$

$$\text{End user hourly preventive maintenance cost} = \frac{\text{Preventive maintenance cost \$/unit time}}{\text{EUH/unit time}}$$

$$\text{End user hourly operations cost} = \frac{\text{Operations cost \$/unit time}}{\text{EUH/unit time}}$$

$$\text{End user hourly training cost} = \frac{\text{Training cost \$/unit time}}{\text{EUH/unit time}}$$

In addition to end user hourly costs, another key index is station hourly costs. The following equation was used to calculate station hourly M&O costs:

$$\text{Station hourly M\&O cost} = \frac{\text{M\&O cost \$/unit time}}{\text{SOH/unit time}}$$

Similar to end user M&O costs, station hourly M&O costs are made up of the same four components: (1) corrective maintenance, (2) preventive maintenance, (3) operations, and (4) training. These components were calculated by simply using the previous four equations for end user hourly costs and replacing EUH with SOH. The average values obtained for the end user hourly cost and the station hourly cost are summarized below for DSS 11 during the nine-week test.

	Average end user hourly cost, \$/EUH	Average station hourly cost, \$/SOH
Corrective maintenance	20.07	12.86
Preventive maintenance	7.38	4.73
Operations manpower	41.81	26.77
Training	16.86	10.68
Total	86.12	55.04

C. Tracking

The number of tracks per week at DSS 11 during this nine-week test varied between 11 and 14. The data lost per week varied from a low of 61 to a high of 185 min, with an average loss of 86 min per week or 7 min per track.

Telemetry data averaged about 85 hours per week, and the lost data of 1.4 hours per week represents about 1.7 percent of the data. This is a conservative number for data lost because it only accounts for lost data when the TPA is out of lock. Additional losses such as between Goldstone and NOCC via the high-speed data line are not included in the above data.

IV. Summary

The data in this article is a preliminary data base collected at DSS 11 during the nine-week period from May 14, 1978, to July 9, 1978. The purpose of this preliminary data base was twofold. First, to initiate a data collection system that will be required to analyze the upcoming DSS 13 unattended operations demonstration, and second, to provide a data base that will serve as a bench mark for comparing the future data collected at DSS 11 and DSS 13 during the automation demonstration.

The results from this preliminary data show that end user hours per week were relatively constant at 102.8, with a coefficient of variation of only 4.5 percent. However, corrective and maintenance manhours varied considerably, with a coefficient of variation of 42.7 and 62.2 percent respectively. Also, there were about two operations manhours for each maintenance manhour. We would expect that for the automated station, the operator manhours would approach zero.

The average operations and maintenance manpower in dollars per end user hour was 88.12 and per station operating hour was 55.04 during the nine-week test at DSS 11.

The telemetry data lost averaged 7 min per track or about 1.7 percent of the data.

V. Future Work

A. DSS 13 Data Base

Data will be collected at DSS 13 and NOCC during the unattended operations demonstration. This data will be similar to the data collected during this initial test period at DSS 11. In addition, more detailed data by subsystem will be collected at DSS 13 for preventive and corrective maintenance. The subsystems at DSS 13 that may require maintenance were summarized by E. Jackson and are shown in Table 5. The DSS 13 subsystems required for automation that would not be found at a typical DSN station are shown with an asterisk in Table 5. The data from this table will allow us to compare maintenance required for items at a regular station to the additional items needed for an automated station.

B. DSS 11 and DSS 13 Data Bases

Data will continue to be collected at DSS 11. Throughout the DSS 13 unattended operations demonstrations, comparable data will also be collected at DSS 13. This will probably mean continuing data collection throughout the rest of calendar year 1978.

C. Comparison of DSS 13 to DSS 11

We will compare the life cycle cost parameters for a conventional DSN station, DSS 11, to an automated DSN station, DSS 13. We will analyze the efficiency and productivity, the end user hourly costs and station hourly costs, and the amount of tracking and data lost for the conventional and automated stations. In addition to these quantitative goals, we will also document qualitative advantages or disadvantages for operating in remote, unattended mode. We also plan to list any trouble areas that may require design or operating changes or that may provide inputs to a future automated station design.

Acknowledgement

We wish to thank Earl Jackson for supplying the DSS 11 data and providing insight into station operation.

Reference

1. Remer, D. S., Eisenberger, I., and Lorden, G., "Economic Evaluation of DSS 13 Unattended Operations Demonstration," PR 42-45, Jet Propulsion Laboratory, Pasadena, Calif., pp. 165-171.

Table 1. DSS 11 data base

Parameter	Week ending dates, 1978								
	05/14	05/21	05/28	06/04	06/11	06/18	06/25	07/02	07/09
Station operating hours	160	168	160	160	160	160	160	160	160
End user hours	109.4	97.6	96.7	105.7	103.6	102.1	101.7	99.1	109
Tracking hours	78.8	89.8	75.9	96.3	85.6	81.1	79.4	89.4	85.4
Operation manhours	386.8	283.6	294.2	344	354.3	295.7	330.7	292	360.1
Data lost hours	2.47	2.81	0.39	0.93	1.42	1.02	1.20	1.40	1.03
Number of tracks	12	13	14	14	11	12	11	10	12
Preventive maintenance manhours	18.7	55.1	93.05	34.5	112.1	64.4	86.4	14.1	29.4
Corrective maintenance manhours	70.5	55.25	82.33	202.45	219.1	211.5	183.75	159.7	196.5
Training manhours	54.5	171.3	79.9	106.7	74.5	156.7	179.5	194.8	158

Table 2. DSS 11 end user hour allocation

Week ending May 14, 1978, through week ending July 9, 1978	
Spacecraft tracking	91.8%
Project related support	4.0
Radio science	2.2
DSN project preparation	1.6
DSN engineering	0.4
	100.0

Table 3. DSS 11 station operating hour allocation

Week ending May 14, 1978, through week ending July 9, 1978	
Spacecraft tracking	69.3%
Preventive maintenance	14.4
Personnel training	8.4
DSN engineering	3.8
Radio science	1.5
DSN project preparation	1.1
Corrective maintenance	0.9
Project related support	0.6
	100.0

Table 4. DSS 11 life cycle cost parameters

Parameter	05/14	05/21	05/28	06/04	06/11	06/18	06/25	07/02	07/09
Efficiency ratio = $\frac{\text{EUH}}{\text{SOH}}$	0.684	0.581	0.604	0.661	0.648	0.638	0.636	0.619	0.681
M&O EUH productivity = $\frac{\text{M\&O MH}}{\text{EUH}}$	4.85	5.79	5.68	6.51	7.34	7.13	7.67	6.67	6.83
M&O SOH productivity = $\frac{\text{M\&O MH}}{\text{SOH}}$	3.32	3.36	3.43	4.30	4.75	4.55	4.88	4.13	4.65
End user hourly M&O cost = $\frac{\text{M\&O cost}}{\text{EUH}}$	64.08	76.57	75.55	86.28	97.48	94.68	101.76	88.27	90.45
End user hourly OC = $\frac{\text{OC}}{\text{EUH}}$	46.56	38.27	40.30	42.86	45.04	38.14	42.82	38.81	43.51
End user hourly MC = $\frac{\text{MC}}{\text{EUH}}$	10.96	15.19	24.37	30.13	42.97	36.32	35.70	23.57	27.85
End user hourly TC = $\frac{\text{TC}}{\text{EUH}}$	6.56	23.11	10.88	13.29	9.47	20.22	23.24	25.89	19.09
Station hourly M&O cost = $\frac{\text{M\&O cost}}{\text{SOH}}$	43.78	44.48	45.53	57.0	63.11	60.42	64.69	54.68	61.63
Station hourly OC = $\frac{\text{OC}}{\text{SOH/week}}$	31.80	22.23	24.22	28.31	29.16	24.34	27.22	24.04	29.64
Station hourly MC = $\frac{\text{MC\\$/week}}{\text{SOH/week}}$	7.49	8.83	14.73	19.91	27.82	23.18	22.69	14.60	18.98
Station hourly TC = $\frac{\text{TC\\$/week}}{\text{SOH/week}}$	4.49	13.42	6.58	8.78	6.13	12.90	14.78	16.04	13.01
Manpower ratio 1 = $\frac{\text{Operations MH}}{\text{Maintenance MH}}$	4.95	4.12	2.13	1.90	1.29	1.64	1.89	2.80	2.29
Manpower ratio 2 = $\frac{\text{Operations MH}}{\text{Operations MH and Maintenance MH}}$	0.832	0.805	0.681	0.655	0.564	0.621	0.654	0.737	0.696
Lost data ratio = $\frac{\text{Lost data}}{\text{Good telemetry data}}$	0.031	0.031	0.005	0.010	0.017	0.013	0.015	0.016	0.012
Tracking productivity = $\frac{\text{Operations MH}}{\text{Tracking hours}}$	5.60	5.07	4.93	4.68	5.01	5.55	6.43	5.45	6.07
Operations SOH productivity = $\frac{\text{Operations MH}}{\text{SOH}}$	2.76	2.71	2.34	2.82	2.68	2.81	3.19	3.04	3.24
Operations EUH productivity = $\frac{\text{Operations MH}}{\text{EUH}}$	4.03	4.66	3.87	4.26	4.14	4.41	5.02	4.91	4.75

Abbreviations:

EUH = end user hour
SOH = station operating hour
MH = manhour
M&O = maintenance and operations
OC = operating cost
MC = maintenance cost
TC = training cost

Table 5. DSS 13 Maintenance activities data sheet

Week Ending__________

PREVENTIVE MANHOURS:

26-m Antenna

Hydraulic Systems __________

Electronic Systems __________

*Control Computer (MODCOMP II/25) __________

*Clock __________

*Terminetr __________

*Microprocessor __________

Waveguide Configuration Assembly __________

Low Noise Amplifier (Maser)

Maser Compressor __________

Refrigerator __________

Block III Receiver __________

Block III SDA __________

*108 KHz Subcarrier Oscillator (Microwave Link Transmission) __________

*Station Controller (8080 based microcomputer) __________

Star Switch & Controller __________

*SDA Controller __________ *Block III Receiver Controller __________

*Waveguide Configuration Assembly Controller __________

High Speed Data Line

Data Set __________ Microwave Line Channel __________

CORRECTIVE MANHOURS:

26-m Antenna

Hydraulic Systems __________

Electronic Systems __________

*Control Computer (MODCOMP II/25) __________

*Clock __________

*Terminetr __________

*Microprocessor __________

Waveguide Configuration Assembly __________

Low Noise Amplifier (Maser)

Maser Compressor __________

Refrigerator __________

Block III Receiver __________

Block III SDA __________

*108 KHz Subcarrier Oscillator (Microwave Link Transmission) __________

*Station Controller (8080 based microcomputer) __________

Star Switch & Controller __________

*SDA Controller __________ *Block III Receiver Controller __________

*Waveguide Configuration Assembly Controller __________

High Speed Data Line

Data Set __________ Microwave Link Channel __________

*Automation Equipment